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GEOLOGY OF OIL AND GAS IN RELATION TO COAL.

By

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There has long existed an idea that oil and gas are somehow related to coal if, indeed, not derived from coal. The occurrence of oil, gas, and coal in the same areas in many parts of the world, coupled with the fact that gas is given off from coal in mines and that both oil and gas can be distilled from coal, is largely responsible for this idea. Granting that this geographic relationship is purely fortuitous; the more serious question arises: Just what are the relations of coal, oil and gas in their origin, character and occurrence?

All are hydrocarbons, that is, consist of carbon and hydrogen with some oxygen and nitrogen and possibly other substances. If coal be heated in a retort, oil and gas are given off which have many of the properties of oil and gas as found in nature and separable into much the same series of primary compounds.

Furthermore, our common theories of the origin of all three describe them as derived from the remains of organic material. Mr. Reinhardt Thiessen has shown that coal is made up of remnants of land and water plants that may have accumulated originally as a peaty deposit. Similar studies on the "oil shales" of Colorado by C. A. Davis show that those shales consist in the main of plankton mixed with mud. Plankton is the gelatinous material composed of the remains of water weeds and small lake animals that accumulates at the bottom of lakes.

Chemical and microscopic studies of cannel coal indicate that it lies about half way between bituminous coal and oil shale. It, too, is a water deposit but appears to differ from the shale in that while



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the shale contains principally the remains of gelatinous water plants, cannel coal contains mainly the spores and decomposition products of the spores of ferns and other plants such as made up the bituminous coals.

It would seem, therefore, that bituminous coal, cannel coal, and oil shale differ in that bituminous coal is derived from the remains of land or water plants, with more or less woody parts, which grew where the coal is found; cannel coal is derived mainly from the spores of these same land and water plants floated to the place where the cannel coal is now found, usually lagoons within the coal swamp; and oil shale derived its bituminous material from water plants and small animals accumulated on the bottom in open bodies of water.

Oil and gas differ from coal in one important particular. Coal stays where it was put. Oil and gas, as a rule, do not or, at least, we suppose that they do not because they can move through the rocks and we believe that they were not deposited originally in the sands where they are commonly found today. That water can travel long distances through rocks, possibly hundreds of miles, is proved by our knowledge of artesian waters. That gas can and does travel through the rocks at least a few miles, is well established by a study of gas occurrences and rock pressures in the gas fields. That oil will travel short distances is very well established. That it will travel long distances seems a safe inference from our knowledge of the movement of water in the rocks.

Then comes the all important problem: How do oil and gas travel? Gas, we know, travels in two ways: by its own expansion, from high pressure to low pressure areas; and by being pushed ahead of liquids advancing with superior pressure. Oil may be said to travel in four ways: First, it runs down hill under the attraction of gravity. Second, it will move forward under the influence of a gas exerting an unbalanced pressure on one side. Third, it will rise to the surface of a heavier liquid and ride on top of such a liquid if moving. Fourth, it will move through minute spaces by capillary attraction, as when oil rises in the wick of a lamp. Apparently all four of these conditions exist in nature.

To get more clearly in mind the conditions under which oil and gas accumulate in the rocks - for it is this accumulation which has practical interest - let us recall: First, that the beds of rocks differ in porosity and that the same bed differs greatly in porosity within itself. Second, that practically no rock lies exactly flat but all are tilted or folded in various degrees. The terms "monocline", "anticline", "syncline", "bench", "saddle", "nose", "dome" and "basin" are familiar. Third, that it may be doubted if oil will commonly run out of a rock except under pressure of either gas, air, or artesian water. This is clearly shown where supposedly exhausted oil fields are revived by admitting gas, air or water under pressure.

Experiments indicate that the producing oil sands have a porosity of one-tenth to one-fourth of the volume of the rock, with an average of around one-fifth. Therefore, a little difference in the pore space may determine if a rock is productive or dry. In many fields the pore

space seems to be the principal or only factor in determining where oil and gas will be found. In others, it is only one of the factors.

Oil may occur in association with water or in a "dry" or "water free" sand. It is probably always associated with some gas, though gas is not always accompanied by recoverable oil.

Where water, oil, and gas occur in the same stratum in intercommunicating space, they arrange themselves in the rock in the order cited, from the bottom up. Thus the gas is found in the highest part of the rock reservoir or only on the anticlines. The oil is found on the flanks of the anticlines and the water in the synclines. This simple theoretical arrangement, however, seldom holds good, as will be evident to any one who studies the structural relations of the oil and gas pools of southwestern Pennsylvania. In the first place, beyond 3,000 feet below the surface, there is an increasing tendency of the sandstones to be water free. The same sandstone that contains water in eastern Greene County, Pennsylvania, may be dry in western Greene County where it is several hundred feet deeper. Again, few or none of the anticlines are flat crested but rather "camel backed", not only rising irregularly into domes and saddles but having a general rise along their axes toward one end. Thus, practically all of the anticlines and synclines of western Pennsylvania have a general rise from the southwest toward the northeast, so that the top of an anticline at one point may be much lower than the bottom of the syncline either side at points a few miles to the northeast. Under these conditions, if a bed of sandstone is partly filled with water and the top of this water forms a level, as it will if free to move, it is obvious that water level will be on top of the anticline at one point and in the bottom of the adjoining synclines a few miles northeast. It follows that if there is oil lying on the water, this oil will lie on the anticline in one area, (with gas, if present, farther up the same anticline) and in the syncline farther northeast where the synclines have risen above the water level.

These statements give a slight idea of the difficulty of predicting the presence of oil and gas in any area without a very wide and comprehensive study of all of the conditions (not including the pore space of the rocks, which cannot even be guessed at from the surface). For example, in a given stratum or "sand" in eastern Greene County, oil is found above water. How may we predicate the presence of either oil or gas farther to the west where the sand is deeper and contains no water? We do find both oil and gas in the water-free sands where deeper farther to the west. How did they get below the water? Has the water been driven past them out of the deeper rock or is the water working its way down from the surface? In places water and oil are pumped together from the wells as though in those places the water were passing the oil either up or down as the case might be, and had not yet reached the natural order of arrangement with reference to weight.

These are a few of the problems that the new Geological Survey has set itself to try to work out for Pennsylvania and it is hoping to reach some definite, helpful conclusions before the oil and gas fields of the State have become only a memory. The hopeful element

in the problem is our belief that the oil fields are yet a long way from exhaustion if a method can be found to get from the sands all the oil not yet pumped out. For example, a sand with a pore space of $1/5$ (20%) has a capacity of about 1,550 barrels of oil per acre foot. The Bradford field in McKean County is estimated to contain 85,000 acres and the sand is estimated to have an average productive thickness of 45 feet. Assuming 1,000 barrels to the acre foot (for the sand is closer grained at Bradford than most sands) gives a total capacity of 3,825,000,000 barrels. The estimated total production to date is 230,000,000 barrels or about $1/16$ of the total. We do not, of course, know the exact porosity of the Bradford sand nor that the pore space in that sand is full of oil. The figures, however, show that even if the pore space is over estimated and the thickness of the productive sand also over estimated, there still is room for the production of many times as much oil as has yet been obtained from that field. Whether the same condition is true in other fields where the sand is more open grained, is not yet certain, but the evidence at hand points to the fact that the supposed exhaustion of most of the oil fields is really the exhaustion of the gas or water pressure that previously forced the oil into the wells. The problem is to get out the oil remaining.

Lest anyone think that because of these difficulties the possible presence of oil or gas cannot be predicted, let me hasten to state that, given time for investigation, the geologist can be of very great service to the oil and gas industry. He can never reach 100% efficiency, but considering the cost of oil and gas wells, if he can reduce the failures from one in three to one in five, his services certainly are worth while. As evidence of this, Mr. F. G. Clapp has estimated that in nine townships of northern Oklahoma success in drilling increased from 60% before geologic advice was sought to 87% following geologic advice. Dorsey Hager has shown that of the new pools opened in Oklahoma between 1913 and 1917, 70% were found on geologic advice. Under scientific direction one wild cat well out of three found oil as against one out of one hundred and fifty drilled in the usual haphazard way. Hager also finds that out of seventy five most important oil pools in Oklahoma and Kansas discovered during those years, all but four were on well defined structures such as domes, anticlines and terraces.

Unfortunately, it is not possible to reach the same success in most fields. For example, in parts of Texas and Louisiana, the surface geology bears little relation to the underground geology and the geologist can be of little help except as he interprets drilling as it progresses and on that basis guides new drilling.

In the Appalachian oil and gas field, which at least is nearer home, it may be noted: first, that much of the area lies within the Appalachian coal field and that within the coal field oil is confined to those areas where the coal is fairly high in volatile matter, having a fuel ratio of 2 or less. A possible cause for this is discovered when we remember that all the coal was originally high in volatile matter and that the low volatile coals have had part of the volatile matter driven off by the forces that folded the rocks; and if we note also that the black shales of the same region, when distilled

for oil, yield no oil in the area of the anthracite coal, little oil in the region of the high carbon coals and much oil in the regions of the high volatile coals. Evidently the lack of oil in the areas of high carbon coals is because the oil has been driven off or distilled into gas.

If we recall that coal, when distilled, will yield oil if heated to a moderate temperature, say less than 750°F., and gas, if heated to a high temperature, say 1200°F., we might expect to find gas in areas of moderately high carbon coals and so we do. Thus if prospecting within the coal field, we might anticipate finding gas but not oil where the coal has a fuel ratio between 2 and 3.5, oil and gas if the fuel ratio is below 2, and neither oil nor gas if the fuel ratio is much above 3.5.

In the second place, oil and gas are found so commonly in association with folds in the rocks it even has been suggested that the oil or gas is distilled only in the rocks where found and by the folding in those places.

It is more likely that the folds have served as places of accumulation because they interrupt the movement of oil on water. Obviously oil working its way down a slope which meets no obstacle, will ultimately land in the adjoining syncline. Or, if being carried up a slope under the pressure of accumulating water, it will ultimately gather on top of the anticline. If, however, in moving down a long slope a flat place or slightly reversed dip is encountered, some of the oil is apt to lodge there; or, if water accompanies the oil, the water may lodge on the flat or bench and form a seal that holds the oil above it so that the oil may be found not on the bench but at the foot of the slope above the bench. Again, it is found that in places on long even monoclines there are folds parallel to the dip making what on a hillside we would call noses and ravines. Experience has shown that many such structural "noses" or "ravines" are the site of good oil pools.

Such facts suggest that the most likely explanation of accumulations of oil and gas in structures on the flanks of anticlines or on monoclines, is that the folding at these points has slightly changed the minute structure of the rock. A careful study of bent slabs of rock in grave yards or in buildings reveals a certain amount of almost microscopic fracturing where the rock has stretched, even though the bend is so slight as to be hardly noticeable. It would seem quite possible, therefore, that such local folding as I have mentioned might open up the rock in one area and tend to seal it in another. If, as many think, oil travels by capillarity, such a change in the character of the rock would tend to retain the oil and create a pool at the fold.

Discussion is omitted of the one hundred and one finer points of the subject, such as the fact that in Pennsylvania the structure of the oil and gas sands does not quite agree with the surface structure, due principally to an unconformity at the base of the Pottsville; the effect of unsymmetrical folding of the anticlines; and so on.

In conclusion, if asked to examine any area for oil and gas, the following procedure is suggested: 1. Study the fuel ratio of coals or the oil content of black shales if they are present. 2. Prepare as accurate a structure contour map of a surface key rock as conditions will permit (if in a region of gently dipping monocline, ten foot contours should be obtained, using a plane table). 3. Prepare a structure contour map of each oil-or gas-bearing sand, using "convergence sheets", that is, sheets showing the varying intervals from that sand to the surface key rock. 4. Study carefully local peculiarities - water conditions, porosity or grain of "sand", flow curves of oil wells, rock pressure of gas, variations of rock pressure in different wells as indicating "lay" of the pool and at various times as indicating the life of the pool.

With these data on hand, you are ready to "go to it".

